CLAIMS

1. Apparatus for spacing two relatively rotatable facing surfaces in use by entraining gas between the surfaces, the apparatus including:

a first portion (1) defining a generally frusto-conical surface (3);

a second portion (2) defining at least one flat surface disposed adjacent the first portion so that the two surfaces face each other and define at least one point of closest engagement between the surfaces, with diverging gaps extending between the surfaces on either side of a plane which contains the point or points of closest engagement and which extends generally orthoginal to the direction of relative rotation, and

a device (4) for biasing the flat surface towards the frusto-conical surface to maintain the gaps within a predetermined dimensional range.

2. Apparatus as claimed in claim 1 wherein the second portion (2) defines a plurality of spaced substantially flat surfaces arranged circumjacent the frusto-conical surface (3) to define respective points of closest engagement and associated gaps.

3. Apparatus as claimed in claim 1 or claim 2 wherein the surfaces (2, 3) engage at the point of closest engagement when the portions are not rotating relative to each other.

4. Apparatus as claimed in any one of claims 1 to 3 wherein the first portion (1) is rotatably mounted and the second portion (2) is non-rotating.

5. Apparatus as claimed in any one of the preceding claims wherein the second portion includes a carrier (10) and at least one tile element (2) mounted on the carrier to define the flat surface.

6. Apparatus as claimed in claim 5 wherein the or each tile element (2) is pivotably mounted on the carrier (10).

7. Apparatus as claimed in any one of claims 2 to 6, including a plurality of said biasing devices (4), each said biasing device being associated with a respective said flat surface (2).

8. Apparatus as claimed in claim 6 wherein there is a series of points of closest engagement defining a line and the or each pivot (5) lies in the plane which contains the line.

9. Apparatus as claimed in any one of claims 2 to 6, wherein the biasing device (4) acts on the plurality of spaced flat surfaces (2).

10. Apparatus as claimed in any one of the claims 5 to 8 wherein the carrier (10) is annular and there are a plurality of tile elements (2) arranged around the carrier.

11. Apparatus as claimed in any one of claims 5 to 9 wherein the or each tile element (2) is generally rectangular.

12. Apparatus as claimed in claim 10 wherein two opposing sides of the tile or each element (2) are curved.

13. Apparatus as claimed in claim 12, wherein one of the curved sides of the tile (2) has a radius substantially equal to or greater than the outer radius of the conical surface (3) and the other curved side of the tile has a radius substantially equal to or less than the inner radius of the conical surface.

14. Apparatus as claimed in Claim 13 wherein the radial depth of the tile is 10 - 15% greater than that of the conical surface.

15. Apparatus as claimed in any one of the claims 1 to 10 wherein the surfaces (2, 3) are relatively positioned in the direction of relative rotation such that the torques generated on the flat surface by the entrained gas are balanced about the point or points of closest engagement.

16. Apparatus as claimed in any one of the preceding claims including a mechanism for rotating the first portion.

17. Apparatus as claimed in any one of the preceding claims wherein the first portion (1) and/or the second portion (2) is formed of or coated by a ceramic material.

18. Apparatus as claimed in any one of the preceding claims wherein the frusto-conical surface (3) is part of a right circular cone.

19. Apparatus as claimed in any one of claims 1 to 17 wherein the generally frusto-conical surface (3) is concave or convex.

20. Apparatus as claimed in any one of the preceding claims wherein the biasing device (4) includes a wave spring, a thrust bearing and/or a set of coil springs.

21. Apparatus as claimed in any one of claims 5 to 8, further including a third portion (2') defining at least one flat surface disposed adjacent a further frusto-conical surface on the first portion (1) and substantially opposite the second portion (2) such that the forces generated by the second and third portions are substantially equal and opposite.

22. A tile bearing pivot incorporating apparatus as claimed in any one of claims 1 to 21, further including a thrust connection (14) for transmitting thrust, but not rotation.

23. A tile bearing pivot as claimed in claim 22, wherein the thrust connection includes a projection (14) cooperating with a recess or cavity (15).

24. A tile bearing pivot as claimed in claim 23, wherein the cavity (15) and the projection (14) include corresponding partially spherical surfaces.

25. A gas seal incorporating apparatus as claimed in any one of claims 1 to 21, wherein the separation of the surfaces (2, 3) is sufficiently narrow to form a seal.

26. A gas seal as claimed in claim 25, further including a path between the outside edge of the first and second portions (1, 2) to limit the flow of air or gas around the back of the second portion.

27. A gas seal as claimed in claim 23 or 26, wherein the first portion (1) is connected to or provides a first sealing surface (28), and
the second portion (2) is connected to or provides a second sealing surface (31) which forms a seal with the first sealing surface.

28. A gas seal as claimed in claim 27, wherein the second sealing surface (31) is located within a housing (34) having a ring (40), the second sealing surface being slidable on the ring so that it can be brought in and out of contact with the first sealing surface (28).

29. A gas seal as claimed in claim 28, wherein the housing includes a recess (33) behind the second sealing surface (31).

30. A gas seal as claimed in claim 29, wherein the biasing device is or includes an axial wave spring (37) housed in the recess (33).

31. A gas seal as claimed in any one of claims 27 to 30, wherein the ring (40) includes an upstand portion (41) for retaining the components of the seal together in a pre-assembled condition.

32. A gas seal as claimed in claim 31, wherein the upstand portion (41) forms an air dam (39).

33. A gas seal as claimed in any one of claims 23 to 32 when dependent upon claims 4 and 5, wherein the biasing device (37) deflects the tile element (2) into contact with the first portion (1) when the first portion ceases to rotate.

34. A gas seal as claimed in any one of claims 25 to 33, further including an axially moveable tile carrier (44) defining a radial sealing surface (48) for forming, with a further radial sealing surface (49), a radial seal to separate internal and external pressure areas (P_1, P_2) and an axially sealing surface (45) cooperating with an axially slidable seal (46) to separate the internal and external pressure areas whereby the radial location of the seal is selected such that the pressure applied by the internal and external pressure areas to the radial sealing surface is substantially balanced by at least the internal and external pressures applied to respective pressure-balancing surfaces opposing the radial sealing surface.

35. A gas seal as claimed in claim 34, including a piston ring (47) between the surface (45) and the seal (46).

36. A gas seal as claimed in claim 35, wherein the tile carrier (44) is provided with a cylindrical sliding surface (52) containing a groove into which is fitted a piston sealing ring (53), the sliding surface and the piston sealing ring cooperating with a cylindrical bore formed in a seal static back

member (54) such that the cylindrical bore together with the cylindrical surface (46) and the tile carrier define a closed annular space (55).

37. A gas seal as claimed in claim 36, further including a valve for venting the enclosed gas space (55).

38. A gas seal as claimed in claim 37, wherein venting of the enclosed gas space (55) causes the tile carrier (44) to withdraw from engagement with the further radial sealing surface (49).

39. A gas seal as claimed in any one of claims 24 to 38, further including a containing ring (57) defining a space (60) for containing any debris resulting from a tile failure.

40. A gas seal as claimed in claim 33, wherein the rotating face seal (61) is at least partially formed of or coated with an abradable material (63) so that in the event of a tile failure the unbalanced forces drive cutting blades (65) on the tile carrier (64) into contact with the material so that it is abraded away, thereby preventing contact between the pressure-balancing surface and the radial sealing surface.

41. A gas seal as claimed in claim 33, wherein the tile carrier (64) is at least partially formed of or coated with an abradable material so that in the event of a tile failure the unbalanced forces drive cutting blades on the rotating face seal (61) into the abradable material, the material being abraded away, thereby preventing contact between the pressure-balancing surface and the radial sealing surface.

42. A gas seal as claimed in claim 40 or 41, wherein the tile carrier (64) includes a device (67, 68) for limiting axial travel of the tile carrier (64).

43. An axially moveable tile carrier (44) defining a radial sealing surface (48) for forming, with a further radial sealing surface (49), a radial seal to separate internal and external pressure areas (P_1, P_2) and an axially sealing surface (45) cooperating with an axially slidable seal (46) to separate the internal and external pressure areas whereby the radial location of the seal is selected such that the pressure applied by the internal and external pressure areas to the radial sealing surface is substantially balanced by at least the internal and external pressures applied to respective pressure-balancing surfaces opposing the radial sealing surface.

44. Apparatus including two relatively rotating grooveless surfaces (1, 2) arranged such that, over a normal design rotation range, the two surfaces are held apart at a gap due to self-generated air or gas pressure existing between the surfaces which, by acting on discrete areas, produces a force aligned in an axial direction relative to the axis of the rotation, the force being balanced by a biasing device (4) to maintain the gap.

45. Apparatus as claimed in claim 44, wherein one of the surfaces (3) is generally frusto-conical and the other surface is flat.

46. Apparatus for spacing two relatively rotatable facing surfaces in use by entraining gas between the surfaces, the apparatus including:

a first portion (1) defining a generally frusto-conical surface (3);

a second portion (2) defining at least one flat surface disposed adjacent the first portion so that the two surfaces face each other and define at least one line of closest engagement between the surfaces, with diverging gaps extending between the surfaces on either side of the line or lines of closest engagement, and

a device (4) for biasing the flat surface towards the frusto-conical surface to maintain the gaps within a predetermined dimensional range.

47. A method of forming part of a labyrinth seal during a seal assembly pre-run, the method including steps of allowing circular cutting blades (63) on a tile carrier portion (64) of the seal assembly to drive into another portion (61) of the seal assembly formed of or coated by abradable material, the axial distance moved by the tile carrier terminating beyond the normal running position of the seal assembly.

48. A method of forming part of a labyrinth seal during a seal assembly pre-run, the method including steps of allowing circular cutting blades (63) to drive into a tile carrier portion (64) of the seal assembly formed of or coated by abradable material, the axial distance moved by the tile carrier terminating beyond the normal running position of the seal assembly.

49. A thrust bearing incorporating apparatus substantially as described herein above with reference to Figures 4 and 5 and/or 14.

50. A gas seal incorporating apparatus substantially as described herein above with reference to Figures 6, 7, 8, 9, 12, 13, 14 and/or 15.